Necessary Bandwidth Description Exhibit

The necessary bandwidth for the radios seeking experimental authorization was listed as 36.5 kHz for the UHF frequency transmitter, 13 kHz for the VHF frequency transmitter, and 26 MHz for the 915 MHz/ISM band transmitter.

144 MHz and 440 MHz Band Description:

An assumption used in calculating the necessary bandwidth is from "*Space Mission Analysis and Design*". This source states that for Frequency Shift Keying (FSK) operation, a bandwidth of at least twice the expected data rate is required for proper separation of the Frequency1 and Frequency2 values about the center frequency for digital communication.

The Kenwood UHF and VHF radios are to be operated at 1,200 bps and 9,600 bps throughput data rate. Twice this yields a value of 2.4 kHz and 19.2 kHz bandwidth respectively.

The product data sheet for the Kenwood TH-D72A states that the radio can experience up to 5 kHz deviation from crystal oscillation errors, and an additional 2.25 kHz due to thermal errors.

Additionally, "*Space Mission Analysis and Design*" also details how to account for Doppler shift due to the satellites high relative velocity to the Earth. Doppler shift is calculated by multiplying the relative velocity of the spacecraft (6,900 m/s worst case) by the center frequency, and dividing by the speed of light.

For the UHF radio, this yields a Doppler shift of 10 kHz and for the VHF radio a Doppler shift of 3.4 kHz.

Summing all of the disturbances for each unit; data rate, crystal deviations, thermal errors, and Doppler shift, the final necessary bandwidth for the 440 MHz band unit is 36.5 kHz and 13 kHz for the 144 MHz band unit.

915 MHz Band Description:

The necessary bandwidth for the Digi XTend 915 MHz band radio was stated at 26 MHz. This is because this unit operates using Frequency Hopping Spread Spectrum (FHSS) protocol. The unit will automatically switch between 50 intermediate frequencies in the range from 902-928 MHz, hence it has the possibility to span up to 26 MHz.

Since the data throughput is 9,600 bps on FSK, using the method from "*Space Mission Analysis and Design*" says that at any point in use the unit will be using 19.2 kHz of bandwidth, centered about the hopping center frequency (902-928 MHz).

Normally the use of such a radio would not be ideal for spacecraft use, since the high ground speed would bring about Doppler shift problems that would be hard to account for with FHSS. However, since this unit is intended to operate in a spacecraft-to-spacecraft fashion, the relative velocities are small and will not hamper use.

References:

Larson, W.J., Wertz, J.R., "Space Mission Analysis and Design," 3rd Ed. Boston, Microcosm Press, 2004.